Ethical discourse on the use of genetically modified crops: A review of academic publications in the fields of ecology and environmental ethics

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ARTICLES

Ethical Discourse on the Use of Genetically Modified Crops: A Review of Academic Publications in the Fields of Ecology and Environmental Ethics

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Abstract The use of genetically modified plants in agriculture (GM crops) is controversially discussed in academic publications. Important issues are whether the release of GM crops is beneficial or harmful for the environment and therefore acceptable, and whether the modification of plants is ethically permissible *per se*. This study provides a comprehensive overview of the moral reasoning on the use of GM crops expressed in academic publications from 1975 to 2008. Environmental ethical aspects in the publications were investigated. Overall, 113 articles from 15 ecology, environmental ethics, and multidisciplinary science journals were systematically reviewed. Three types of moral concerns were used to structure the normative statements, moral notions, and moral issues found in the articles: concerns addressing consequences of the use of GM crops, concerns addressing the act (the technique itself), and concerns addressing the virtues of an actor. Articles addressing consequences (84%) dealt with general ecological and risk concerns or discussed specific ecological issues about the use of GM crops. Articles addressing the act (57%) dealt with the value of naturalness, the value of biotic entities, and conceptual reductionism, whereas articles addressing the actor (43%) dealt with virtues related to the handling of risks and the application of GM crops. The results of this study may help to structure the academic debate and contribute to a better understanding of moral concerns that are associated with the key aspects of the ethical theories of consequentialism, deontology, and virtue ethics.

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Introduction

The use of genetically modified plants[1] in agriculture (GM crops) is controversially discussed in academic publications. An important aspect of this controversy is whether the release of GM crops in agriculture is beneficial or harmful for the environment and therefore acceptable (Hails 2000; Wolfenbarger and Phifer 2000; Clark and Lehmann 2001). Arguments against GM crops include concerns that transgenes might escape into wild populations (e.g., Pilson and Prendeville 2004; Marvier and Van Acker 2005), that the use of herbicide-resistant GM crops might lead to an increase in spraying herbicides (e.g., Firbank and Forcella 2000; Watkinson et al. 2000), and that toxins produced by GM crops might enter the food web and thus affect non-target organisms (e.g., Marvier 2002; Harwood et al. 2005). Moreover, concerns have been raised over the spread of transgenic DNA by horizontal gene transfer to unrelated species (e.g., Ho et al. 1999). Arguments in favor of GM crops are, for instance, that they might be more suitable than traditional techniques to control certain pest species (e.g., Cowgill et al. 2004), that the use of herbicide-resistant GM crops might enhance agricultural biodiversity (e.g., Hails 2002), and that GM crops might require less pesticide use and reduce greenhouse gas emissions (e.g., Brookes and Barfoot 2005).

These scientific arguments are concerned with the potential consequences of the use of GM crops. In addition, it has been asked whether the modification of plants is morally permissible *per se* (Reiss and Straughan 2002). The modification of plants will be morally wrong, if it is regarded as an infringement of the integrity or dignity of plants (e.g., Balzer et al. 2000) or an interference with the natural order (e.g., Verhoog et al. 2003). Such concerns address the process of genetic modification itself. Moreover, there are concerns that are related to the character traits of an actor, such as the concerns that genetic modification is a disrespectful offense against the inherent wisdom of nature (e.g., Deane-Drummond 2002) or a sign of human hubris (e.g., Sandler 2007).

Several review articles have summed up and discussed different moral concerns in the debate on GM crops (e.g., Robinson 1999; Shelton et al. 2002; Weaver and Morris 2005). However, none so far provides a comprehensive overview of the ethical discourse in academic publications on ecological *and* environmental ethical aspects. In 2007 and 2008, we thus carried out a systematic literature review of 15 journals (seven ecology journals, five environmental ethics journals, three multidisciplinary science journals). Our aim was not to reflect the different opinions on gene technology, but to structure the academic discourse by relating the morally relevant concerns and issues expressed in the reviewed articles to

[1] A GM plant is an organism whose genetic characteristics have been modified by the insertion of an altered plant gene of the same species (intragenic modification) or a gene from other organisms (transgenic modification) using genetic engineering (Wartburg and Liew 1999).

established ethical theories. The structure will add a new view point to ethical tools that had already been developed for the decision-making in biotechnology (e.g., Busch et al. 2002; Mepham 2008). Our article will also contribute to the current debate on the ethics of genetically modifying plants (e.g., Balzer et al. 2000).

Methodology

Preparation of the Literature Review

Before the actual literature review, we analyzed moral concerns about GM crops found in various monographs, proceedings, and anthologies about gene technology, plant ethics, risk perception, and related issues (e.g., Runtenberg 1997; Balzer et al. 1998; Rolston 1999; Busch et al. 2002; Heaf and Wirz 2002; Kallhoff 2002; Reiss and Straughan 2002; Ammann et al. 2003; Stewart 2004; Deane-Drummond 2004; Sandler 2007; Stöcklin 2007). Three types of moral concerns were most prominent and thus used to structure the normative statements, moral notions and moral issues found in the subsequent literature review: (1) concerns about the consequences of the use of GM crops in agriculture (in the following called "*moral concerns addressing consequences*"), (2) concerns about the moral permissibility of genetic modification as such ("*moral concerns addressing the act*"), and (3) concerns about human character traits and attitudes that either contribute to or are influenced by using gene technology ("*moral concerns addressing the actor*").

Relevant Ethical Theories

The three types of moral concerns can be linked to well known theories in environmental ethics (cf. Brennan and Lo 2008)[2]: (1) moral concerns addressing consequences to *consequentialism*, (2) moral concerns addressing the act to *deontology*, and (3) moral concerns addressing the actor to *virtue ethics*.

Consequentialism

This normative theory states that the rightness or wrongness of an action has to be judged in light of the value of its consequences (Kutschera 1999; Brink 2006). A consequentialist concept has to define the values that are worth to be promoted by the outcome of an action (Brink 2006), e.g., personal pleasure, satisfaction of personal interests, or perfection of personal essential capacities. In order to find the *best* outcome, alternative actions have to be evaluated and harms and benefits of the consequences of one's action have to be weighed against each other. The one action has to be chosen that promotes the defined value in the best way, which means that

[2] Besides the three mentioned normative ethical theories, other theories exist that are discussed in context of gene technology, e.g., contractualism. However, contractualism as an ethical theory of social contract could hardly be applied to the ethics of GM crops, because plants cannot be part of a social contract. Therefore, deontology, consequentialism, and virtue ethics were chosen as an underlying basis for our analysis.

harms are outweighed by benefits. Consequentialism allows tradeoffs between alternative actions with the aim of maximizing the overall good for the greatest number of morally relevant entities,[3] e.g., maximizing the happiness for the greatest number of people.

Deontology

This normative theory states that the moral evaluation of an action depends on the action's quality, i.e., certain actions are right or wrong per se and thus either permitted or forbidden (Kutschera 1999; McNaughton and Rawling 2006). The rightness of an action is judged based on the action's compliance with a certain rule or principle for the sake of this rule or principle. The balancing between advantages and disadvantages of an action as in consequentialism is not a prime concern. Moral absolutists would state that, as it is the action itself that is important, a morally good act must be performed even if it has a bad consequence (Herold 2008). In addition to this approach, there is a huge diversity of theories that have been described as deontological (Gaus 2001a; Gaus 2001b). For instance, many deontologists do not agree with a moral absolutism and argue that exceptions should be made to avoid catastrophic outcomes (McNaughton and Rawling 2006). Often, deontological theories include considerations of respect for morally relevant entities for their own sake, and considerations of justice.

Virtue Ethics

This normative theory is centered on the individual actor who shows certain virtues. A virtue is a character trait, state or disposition that allows a person to act in a way that individual and collective well-being is promoted. To be named as a virtue, a character trait has to embody a commitment to an ethical value such as justice or benevolence that will provide a built-in ethical guidance for a moral agent (Annas 2006). Virtue ethics implies that acting morally right is based on the actor's moral personal attitudes and convictions. This means that the value of an action can be judged by the value of the virtues leading to this act (Rippe and Schaber 1998). The aim of a virtuous person is to develop an excellent character. Therefore, in virtue ethics an action will be judged as morally good if the actor shows a virtuous character (Annas 2006). Apart from pure forms of virtue ethics various pluralistic forms exist that allow non-virtue-based reasons that also play a role in deontology or consequentialism (Hursthouse 2003; Crisp 2003).

Although the three classical normative theories form the basis of our analysis, we do not classify these concerns in the literature review as consequentialist, deontological, or virtue concerns. This would be problematic as there exist, for instance, forms of so called non-teleological consequentialism that evaluate the outcome of an act in applying *deontological criteria* (cf. Birnbacher 2007). This means that the consequences of the act are morally judged by the number of

[3] Biotic entities can be single organisms, species, ecosystems, or the biotic community.

Table 1 Overview of journals reviewed and number of relevant articles found (in brackets)

Ecology journals (15)	IF	Environmental ethics journals (74)	IF	Multidisciplinary science journals (24)	IF
Trends in ecology & evolution (5)	14.1	Journal of agricultural and environmental ethics (55)	0.7	Science (8)	30.0
Annual Review of Ecology, Evolution, and Systematics (1)	9.8	Environmental Ethics (2)		Nature (11)	26.7
Ecology Letters (0)	7.6	Environmental Values (9)		Gaia (5)	
Ecological Monographs (0)	7.1	Ethics & The Environment (3)			
Frontiers in Ecology and the Environment (2)	4.8	Ethics in Science and Environmental Politics (5)			
Molecular Ecology (1)	4.8				
Ecology (2)	4.8				
Journal of Applied Ecology (3)	4.5				
Journal of Ecology (0)	4.2				
Ecological Applications (1)	3.5				

If applicable, the impact factor (IF, 2006) is shown

individual rights that are respected or by the number of intrinsically right or wrong actions, which result as further consequences from doing the act (Birnbacher 2007). Moreover, many deontologists include consequences in their moral reasoning. However, the normative statements, moral notions, and moral issues found in the articles can be assigned to the key issues of the normative theories, i.e., the moral concerns addressing consequences, the act itself, or the actor.

Review of the Academic Literature

We pre-selected 18 journals from the fields of ecology and environmental ethics as well as multidisciplinary science journals for review (see Table 1). The period reviewed was from 1975 (first conference on the safety of recombinant DNA research in Asilomar, California; see Stewart 2004) to 2008. In the initial selection process, we asked colleagues from biology and philosophy to indicate suitable journals for the literature review. Based on this information, the ten ecology journals with the highest impact factor in 2006[4] (start of study) were selected. As for most journals in environmental ethics no impact factor was available at that time, those journals were chosen that were recommended by *all* colleagues, i.e., five renowned environmental ethics journals dealing specifically with ecological and agricultural topics. In addition, three important and well-renowned multidisciplinary science journals were selected (Table 1).

Environmental ethics journals were selected as we supposed that the ecological and environmental ethical debate about GM crops will primarily take place in this type of journals. Nevertheless, we also wanted to investigate whether moral

[4] The journals were selected in 2007. At this time, the most recent impact factor was from 2006.

Table 2 Keywords used in the search for relevant articles

Keywords 1	Keywords 2	Keywords 3
Gene(s)	Engineering	Plant(s)
Genetic(s)	Modification(s)	Crop(s)
Genetical(ly)	Modify/ied	
Transgene(s)	(Bio)technology/ies	
Transgenic(s)		
GM(O)		

Keywords in the first column were used in all different combinations with those in the second and third column

concerns about GM crops are raised in ecology journals. As journals in this field focus primarily on mere empirical questions, we selected a larger number of journals to have a greater chance to find relevant articles dealing with ethical concerns. As our literature review focused on the debate on GM crops in an environmental ethics context, journals from the fields of microbiology, biotechnology, or general moral philosophy were not assessed.

Online search engines of the journals or of JSTOR (Journal Storage)[5] were used to identify relevant articles for the literature review. Different types of keywords were used that referred to the genetic nature of the modification, the modification or engineering itself, and to plants or crops (Table 2). Keywords of one type were used in all different combinations with those of the other two types. In order not to exclude too many articles, we did not refine our search by using keywords like "value," "respect," "dignity," "integrity," "justice," or "risk." For two journals ("Environmental Ethics," "Environmental Values") no online search engines were available. Articles in these journals were selected by studying titles and abstracts.

Initially, more than 3,300 articles from 18 journals were selected and their titles and abstracts briefly examined. Articles that only briefly mentioned ecological or ethical issues or that were book reviews, editorials, and short news articles were immediately excluded. The remaining 250 original research and review articles were studied in more detail. Those articles that actually dealt with ecological or environmental concerns about GM crops from an ethical point of view were identified. Original research articles in ecology journals that did not address the moral relevance of empirical findings they discussed were excluded from the subsequent analysis. Finally, 113 articles from 15 journals remained.[6]

From the normative statements, moral notions, and issues found in the 113 articles, basic semantic units were extracted. These basic semantic units could be, for instance, morally qualified empirical findings such as "harmful impact of GM crops on non-target insects," normative statements such as "gene technology is morally problematic because it is playing God," moral notions such as "dignity of plants," or issues that were related to principles or concepts with underlying moral implications such as the precautionary principle, global justice, or sustainable

[5] JSTOR (Journal Storage) is an online system for archiving academic journals and provides a full-text search of digitized issues of several hundred journals. See Homepage jstor.org.

[6] Full list of all reviewed articles is available from author 1.

development.[7] Basic semantic units were joined to form classes of similar content. For example, the empirical finding "harmful impact of GM crops on non-target insects" was sorted under the header of "impact on species" and the notion "dignity of plants" under "individual biotic entities." The classes of similar content were finally assigned to certain clusters of moral concerns that fell under the header of one of the three moral concerns mentioned above. In order to assign semantic units to one of these concerns, it was necessary to clarify in which conceptual context they were used in the article (e.g., in context of sustainable agriculture or of the character traits of a person).

Semantic units (and thus the articles using them) that dealt with the outcome of the release of GM crops were grouped under the header of *moral concerns addressing consequences*. Articles that addressed consequences in purely empirical ecological terms (e.g., that there is a certain probability that hybrids between wild plants and GM crops can establish in the landscape) were only included in the analysis, if the moral relevance of the outcome was clearly expressed (e.g., certain consequences of the release of GM crops are beneficial or harmful for biodiversity). Articles that dealt with environmental consequences in general terms (e.g., that there are risks for the environment) were only included if their moral relevance was clarified, for instance, by relating this general concerns about consequences to a concern with a normative implication (e.g., sustainability and its underlying concepts of global justice for recent and future generations). However, semantic units that questioned the permissibility of genetic modification *per se* (e.g., arguing against gene technology because of its "unnaturalness") were grouped under the header of *moral concerns addressing the act itself*. Semantic units that were related to personal motivations, states, dispositions, or character traits of a moral agent and thus to a virtue or vice were grouped under the header of *moral concerns addressing the actor*.

Results

Overview of Results

The great majority of articles were published in journals in the field of environmental ethics and almost half of all even in one single journal ("Journal of Agricultural and Environmental Ethics") (see Table 1). With the exception of two articles (Cohen 1977; Dickson 1980), the reviewed literature was published between 1988 and 2008 (Fig. 1). Since then, growing attention to the use of GM crops in agriculture was apparent in the scrutinized literature. Most articles were published between 1999 and 2008.

Almost all articles from ecology journals and most of those from the other two types dealt with moral concerns addressing consequences (Table 3). However, concerns addressing the act or the actor were also prominent in the literature, especially in journals in the field of environmental ethics.

[7] Only ecological concerns underlying these concepts are relevant for our analysis.

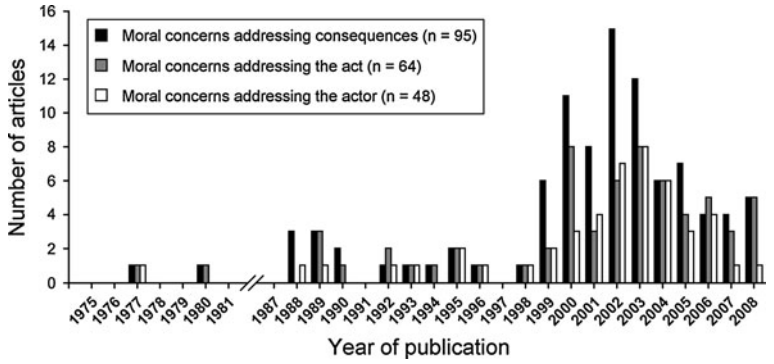

Fig. 1 Number of articles per year in the reviewed period sorted by the three different types of moral concerns

Table 3 Assignment of articles that express a certain moral concern to three different types of journals

	Number and proportion of articles by journal type		
	Ecology journals (15)	Environmental ethics journals (74)	Multidisciplinary science journals (24)
Moral concerns addressing consequences	14/93.3%	64/86.5%	17/70.8%
Moral concerns addressing the act	5/33.3%	49/66.2%	10/41.7%
Moral concerns addressing the actor	4/26.7%	38/51.4%	6/25.0%

Multiple assignments were possible. List of journals in Table 1

Moral Concerns Addressing Consequences

More than 80% of all articles addressed consequences of the use of GM crops in agriculture. They dealt primarily with general ecological and risk concerns and also discussed specific ecological issues about the use of gene technology (Table 4). Overall, 50 articles dealt with both types of concerns, 42 articles only with general ecological and risk concerns, and three articles only with specific ecological concerns.

General Ecological and Risk Concerns

Under this header we grouped all concerns about risk assessment principles or general concepts (e.g., the concept of sustainability) that have ethical implications. Moreover, concerns about ecological risks and benefits that did not further specify the morally relevant entities affected by the presence of GM crops were grouped here. Four groups of moral concerns were present in the literature (see Table 4): concerns related to risk assessment, risk management and risk perception, concerns about (scientific) uncertainty, concerns about sustainable development, and unspecified concerns about ecological risk and benefits.

Table 4 Assignment of articles to moral concerns addressing consequences of the use of GM crops in agriculture

I. Moral concerns addressing consequences (95/84.1%)		
1. General ecological and risk concerns (92/81.4%)	1.1. Concerns related to risk assessment, risk management and risk perception (65/57.5%)	
	1.2. Concerns about (scientific) uncertainty (43/38.1%)	
	1.3. Concerns about sustainable development (28/24.8%)	
	1.4. Unspecified ecological concerns about risk and benefits (58/51.3%)	1.4.1. Socio-economic concerns (35/31.0%)
		1.4.2. Unspecified risk concerns (31/27.4%)
		1.4.3. Unspecified moral concerns (7/6.2%)
2. Specific ecological concerns (53/46.9%)	2.1. Concerns about the consequences for species and individual plants (29/25.7%)	
	2.2. Concerns about the consequences for ecosystems (36/31.9%)	
	2.3. Concerns about the consequences for the environment in general (10/8.8%)	

Multiple assignments of articles were possible. In brackets: number and proportion of articles

Concerns related to risk assessment, risk management, and risk perception were often mentioned or discussed in the literature (see Table 4). Overall, 62 of these articles were related to risk assessment, 12 to risk management, and 21 to risk perception. In 21 articles concerns about risk assessment and risk management were discussed in detail, most often addressing the precautionary principle (e.g., Carr 2002; Mayer and Stirling 2002; Myhr and Traavik 2002; Skorupinski 2002).

Concerns about (scientific) uncertainty were frequently present (see Table 4), but discussed in detail in only nine articles (Kasanmoentalib 1996; Carr and Levidow 2000; Carr 2002; Myhr and Traavik 2002; Myhr and Traavik 2003a; Howard and Donnelly 2004; Böschen et al. 2006; Jensen 2006; Ramjoué 2007). Articles under this header were mostly published in environmental ethics journals (n = 27). Those articles that merely mentioned uncertainty (n = 34) did this most often in the context of discussing environmental risk assessment (n = 29) and consequences (n = 24). Those articles that dealt with uncertainty in detail discussed, for instance, the ethical implications of unknown risks or unpredictable side-effects of GM crops (e.g., Kasanmoentalib 1996) or the concept of "non-knowledge" (Böschen et al. 2006).

Concerns about sustainable development were identified in about a quarter of all articles (see Table 4) and addressed in detail in ten articles. Most articles addressed the contribution of gene technology to the future development of agriculture (e.g., Duvick 1995; Wenz 1999; Pouteau 2000; Snow 2003). The sustainable development of agriculture, including societal questions, was discussed in detail in ecology journals (e.g., Hoffman and Caroll 1995), environmental ethics journals (e.g., Duvick 1995), and multidisciplinary science journals (e.g., Altmann and Ammann 1992).

Unspecified concerns about ecological risk and benefits could be sorted into socio-economic, unspecified risk, and unspecified moral concerns (see Table 4). However, socio-economic concerns were only relevant when they referred to ecological/environmental ethical issues. *Socio-economic concerns* were identified in 35 articles (see Table 4). They included, for instance, concerns about social and environmental justice (e.g., Osborn 2002), concerns about benefits or harms for future generations (e.g., Wambugu 1999), the acknowledgement of "non-scientific" concerns of the public (e.g., Devos et al. 2008), or the establishment of a societal contract with the public (e.g., Bruce 2002a).

Unspecified risk concerns addressed environmental concerns about the release of GM crops that were not further specified. They were identified in 31 articles (see Table 4) and dealt, for instance, with underlying scientific principles for ecologically-based risk assessment (e.g., Regal 1994) or invoked the image of farmers as "stewards of the countryside" who are involved in environmental protection (e.g., Hails 2002). The notion "stewards of the countryside" is related to moral concerns about the actor and thus linked to virtue ethics.

Unspecified moral concerns were present in seven articles (see Table 4) that dealt with general normative aspects of consequences of gene technology. These articles discussed the consequentialist implication of the "harm principle" as such (Holtug 2001), referred to potential benefits or harms of GM crops in context of the "future

benefits argument"[8] (e.g., Burkhardt 2001), or addressed ecological risks in the light of underlying research paradigms of science (e.g., Scott 2005).

Specific Ecological Concerns

Articles under this header were quite common in the assessed literature and mentioned or discussed ecological consequences for individual plants as well as for species, ecosystems, or the environment in general (see Table 4). Consequences in light of the moral status of *individual plants* were of hardly any interest, even in environmental ethics journals. Only two articles (Balzer et al. 2000; Holtug 2001) went into detail about consequences for single plant organisms. Balzer et al. (2000) pointed out that the dignity of individual plants (in this article a consequentialist interpretation is favored) is violated if plants are prevented from performing the functions that members of their species can normally perform. Holtug (2001) addressed the impact of gene technology on individual organisms (in context of the consequentialist "harm principle"), but denied that plants could be violated, because they cannot suffer. Other articles discussed whether the use of GM crops is a violation of the value of *species and ecosystems* (Comstock 1989; Comstock 1990). Articles in this group also stated that certain effects such as gene flow or non-target effects might have (harmful) consequences for the *environment* in general. These articles discussed the impact on agricultural biodiversity in general (e.g., Gura 2001; Hails 2002; Kotschi 2008) or pointed out that farmland biodiversity might be increased by the use of herbicide resistant crops (e.g., Madsen and Sandøe 2001).

Articles that dealt with specific ecological concerns often discussed ecological risks for certain entities on the background of risk assessment and its underlying principles (n = 36), especially the precautionary principle (e.g., Mayer and Stirling 2002; Myhr and Traavik 2002; Howard and Donnelly 2004). They also discussed ecological issues in the context of general concerns about risk and benefits (n = 36), for instance, the question whether the use of GM crops and organic farming is incompatible or not (e.g., Bruce 2003). Moreover, unknown risks and unpredictable side-effects of GM crops on certain species or the environment in general were discussed (n = 24) (e.g., Kasanmoentalib 1996; Clark and Lehmann 2001; Scott 2005). Articles in this group also addressed specific consequences for the environment invoking the concept of sustainable development (n = 16) (e.g., Wenz 1999; Krebs et al. 1999).

Moral Concerns Addressing the Act

Articles under this header addressed concerns about the value of naturalness, the value of biotic entities, and about conceptual reductionism (Table 5). Such concerns were articulated in order to question the permissibility of gene technology *per se*. Overall, 30 articles dealt only with the value of naturalness and six only with the

[8] The "future benefits argument" (FBA) is an utilitarian ethical argument offered by proponents of agricultural biotechnology to justify continued research and development in gene technology.

Table 5 Assignment of articles to moral concerns addressing the act of genetic modification

II. Moral concerns addressing the act (64/56.6%)		
1. Concerns about the value of naturalness (56/49.6%)	1.1. Nature as a safety mechanism (31/27.4%)	
	1.2. Nature as a guiding principle (29/25.7%)	1.2.1. Nature as a given order (18/15.9%)
		1.2.2. Nature as an autonomous identity (19/16.8%)
	1.3. Undefined concerns (9/8.0%)	
2. Concerns about the value of biotic entities (27/23.9%)	2.1. Intrinsic value of holistic biotic entities (22/19.5%)	2.1.1. Intrinsic value of species (11/9.7%)
		2.1.2. Intrinsic value of ecosystems (5/4.4%)
		2.1.3. Intrinsic value of the biotic community (14/12.4%)
	2.2. Intrinsic value of individual biotic entities (5/4.4%)	
	2.3. Undefined concerns (3/2.7%)	
3. Concerns about conceptual reductionism (11/9.7%)		

Multiple assignments of articles were possible. In brackets number and proportion of articles

value of biotic entities. Moreover, one article dealt only with conceptual reductionism. However, 27 articles dealt with two different concerns and three articles with all three concerns.

The term "value"—in this context—means "intrinsic value," i.e., that objects or actions have an end in themselves and cannot be reduced to a mere instrumental value for humans (O'Neill et al. 2006). Some environmental philosophers such as Taylor (1986) distinguished between intrinsic value and inherent worth. In the literature assessed both notions were used in the same sense. The term "intrinsic value," of course, is not limited to moral concerns addressing the act.

Concerns About the Value of Naturalness

Naturalness as a value implies that nature and its order is valuable and good *per se*. Thus, all forms of genetic modification are unnatural and therefore morally wrong. None of the articles from ecology journals or multidisciplinary science journals explicitly referred to the value of naturalness. Overall, 15 articles from the environmental ethics journals discussed concerns about the value of naturalness as such (e.g., Katz 1993; Karafyllis 2003; Verhoog et al. 2003; Siipi 2008). Articles in ecology journals only indirectly addressed concerns about naturalness. Authors argued, for instance, that gene technology just simulates a natural process (Tiedje et al. 1989). They stated that barriers that are crossed by biotechnology are comparable to those constantly crossed in nature (Tiedje et al. 1989). It was also discussed whether gene technology is unnatural in the sense that it is the ultimate manifestation of the cybernetic control of humans (Elliott and Cole 1989).

Nature as a safety mechanism was addressed in 31 articles (see Table 5). This type of concern implies that "nature knows best," because nature is the result of a long evolutionary process (cf. Reiss and Straughan 2002). Therefore, the inherent safety mechanisms of nature should be protected as otherwise there would be a violation of natural evolution (Madsen et al. 2002). The intrinsic value of nature lies in the inherent safety mechanisms of natural evolution and these mechanisms would no longer function as an insurance against disastrous consequences if humans disturb them (e.g., Madsen et al. 2002). The safety net of nature is helpful in situations where humans' assumptions about the functioning of nature might be proved wrong (e.g., Karafyllis 2003). As far as the emphasis is on the avoidance of disastrous consequences, the concept of nature as a safety mechanism can be regarded as a "moral concern addressing consequences" and grouped there. However, if nature as a safety mechanism is subsumed under the header of "moral concerns addressing the act," the intrinsic value of the safety mechanism lies in nature as such, which invokes that the violation of this intrinsic value is morally problematic per se.

Nature as a guiding principle was addressed in 29 articles (see Table 5). These articles dealt either with *nature as a given order* or with *nature as an autonomous identity*. The concept of *nature as a given order* defines nature as a non-human domain or as God's order that humans have to respect. The more human actions or products resemble natural actions or products, the more natural they are, and the more respect humans show for the natural order (Siipi 2008). The natural order,

which has an intrinsic value, can be understood in terms of harmony and balance (Lammerts van Bueren and Struik 2005), self-realization (Katz 1993), God's creation (Comstock 1989) or "something out there" that humans must obey and should not challenge (Madsen et al. 2002). The genetic modification of crops is therefore an infringement of the given order and thus morally wrong.

The concept of *nature as an autonomous identity* states that an inherent purpose can be ascribed to nature as a whole or to single natural entities. When humans intervene in nature and create artifacts, they destroy the autonomy of nature by imposing a system of domination (Katz 1993). By inserting foreign genes into a plant's genome, borders of species are crossed and their identity is infringed. GM crops are therefore unnatural and, in consequence, morally wrong. Human beings are called to respect the autonomy of nature. The concept of nature as an autonomous identity can be linked to the virtue of appreciation (cf. Katz 1993).

Concerns About the Value of Biotic Entities[9]

Articles under this header regarded gene technology as a violation of the intrinsic value of biotic entities, i.e., a disrespect to organisms and life in general. The term "intrinsic value" was either mentioned directly or indirectly by using terms like "integrity" or "dignity." Integrity is defined as the intrinsic value of a biotic entity that accomplishes its natural aim (Lammerts van Bueren and Struik 2005), which includes both individual and holistic entities, whereas dignity is assigned only to individual organisms (Balzer et al. 2000).[10] No one article in the ecology journals or the multidisciplinary science journals dealt with concerns about the value of biotic entities. In six articles published in the "Journal of Agricultural and Environmental Ethics" and in two articles published in the journal "Environmental Values" concerns about the value of biotic entities were discussed in detail. Among these articles, three dealt with the concepts "integrity" and "dignity" (Balzer et al. 2000; Melin 2004; Lammerts van Bueren and Struik 2005), three with the concept of "integrity" (Verhoog et al. 2003; Dobson 1995; Westra 1998), and one with the concept of "dignity" (Heeger 2000). Another article discussed the intrinsic value of animals and also mentioned that of plants (Verhoog 1992).

The *intrinsic value of holistic biotic entities* was addressed in 22 articles (see Table 5). In these articles, an intrinsic value is ascribed to species, (agricultural) ecosystems or the whole biotic community. The *intrinsic value of species* lies in the "wholeness" of species, their ability to fulfill species-specific characteristics, and their being in balance with the environment (Lammerts van Bueren and Struik 2005). Every human action that hinders species to fulfill their species-specific characteristics would be morally wrong. Overall, 11 articles addressed such concerns about the intrinsic value of species (see Table 5).

[9] The term "biotic entities" refers to individual organisms as well as to species, ecosystems, or the biotic community.

[10] Balzer et al. (2000) discussed different meanings and understandings of dignity, including deontological meanings. However, they favoured a consequentialist meaning.

Only five articles addressed the *intrinsic value of ecosystems* (see Table 5) which lies in the harmony and balance of their biotic and abiotic elements (Verhoog et al. 2003; Deckers 2005; Lammerts van Bueren and Struik 2005). Humans should follow the "ecological knowledge of nature" in cultivating the land (Verhoog et al. 2003). As "ecological integrity" results from natural, evolutionary processes, human-induced interferences such as gene technology must be banned (Westra 1998).

The *intrinsic value of the biotic community* was expressed in 14 articles (see Table 5). This value lies in the ability of life for self-regulation in order to accomplish a certain inherent purpose (Lammerts van Bueren and Struik 2005). In this context, integrity is understood as the state of "wholeness" or "completeness" of life allowing it to perform all the functions that are characteristic for the biotic community. Verhoog (1992) discussed this concept in terms of something (recognizable by phenomena such as homeostasis, stability, balance, and equilibrium) that can be disturbed by human actions. Dobson (1995) understood the intrinsic value of the biotic community in a similar way, stating that genetic engineering could be problematic because it is a technology that expresses a world view of human mastery over the non-human world.[11] Overall, eight articles dealing with the value of the biotic community addressed the "land ethics" and cited the well-known notion about the "integrity, stability, and beauty of the biotic community" (Comstock 1989; Verhoog 1992; Dobson 1995; Saner 2000). This integrity can be irreversibly disturbed by human actions such as gene technology (Verhoog 1992).

The *intrinsic value of individual biotic entities* was addressed in five articles (see Table 5). Three articles dealt with both the *concept of integrity* and the *concept of dignity*. One article referred only to the *concept of integrity* and stated that integrity can only be guaranteed if the specific phenotype of an individual plant is in balance with its environment (e.g., Lammerts van Bueren and Struik 2005). Another article pointed to the *concept of dignity*: Balzer et al. (2000) critically discussed a deontological interpretation of dignity and also an interpretation based on the concept of the "telos" (aim of an organism) that corresponds with the genetic make-up of an organism. This interpretation defines a plant's well-being as the potential of the individual (characterized by its genetic make-up) to develop to maturity. According to these meanings of dignity, changing the genome through genetic modification would collide with the integrity or dignity of an organism. This is in line with a deontological interpretation of dignity or integrity and was thus grouped under the header of "moral concerns addressing the act." However, Balzer et al. (2000) favored a consequentialist interpretation of the "dignity of plants."

Concerns about Conceptual Reductionism

Articles under this header addressed the reductionist perspective in handling gene technology. Two different types of reductionism can be distinguished (Woese 2004): a *methodological reductionism* that is the mode of scientific analysis, and a

[11] Concerns about the human mastery over the non-human world are also topics within virtue concerns.

conceptual reductionism that is part of a worldview stating that the whole is no more than the sum of its part. Concerns about conceptual reductionism represent a fundamental critique of the materialistic worldview and of the treatment of biotic entities only as a means to an end and not as ends in themselves. For opponents of gene technology, such a conceptual reductionism is inherent in the genetic modification of plants. In consequence, they condemn gene technology *per se*.

Concerns about conceptual reductionism were rarely expressed in the literature (see Table 5). Articles that dealt with the concern often addressed naturalness or the intrinsic value of organism. For instance, one article stated that in a "process of reduction" the distinctions between the living and the non-living and between the "nature" of plants, animals and humans disappears at the molecular level (Verhoog 1992). As the idea of "crossing species barriers" seems to be irrelevant at the molecular level, humanity is getting further and further away from nature as given to humans (Verhoog 1992). This "reduction of life to the digital code of DNA" is critically related to the fictional character of Frankenstein (Scott 2000) and thus to concerns about the value of naturalness. Moreover, the critique of reductionism was addressed in context of the perception of risks and scientific uncertainties about risks (e.g., Verhoog et al. 2003; Deckers 2005). Linked to this conceptual reductionism were concerns about the moral status of biotic entities (Verhoog et al. 2003; Deckers 2005).

Moral Concerns Addressing the Actor

Articles under this header referred to virtues related to the handling of risks or to the application of GM crops (Table 6). Overall, 26 articles dealt only with virtues related to the handling of risks, 19 only with virtues related to the application of GM crops and three with both types. As concerns addressing the actor are linked to a person's character traits and want to define what constitute a "good life" of humans, they are part of virtue ethics.

Table 6 Assignment of articles to moral concerns addressing the actor

III. Moral concerns addressing the actor (48/42.5%)		
1. Virtues related to the handling of risks (29/25.7%)	1.1. Virtues related to trust in actors to handle risks (22/19.5%)	1.1.1. Trustworthiness
	1.2. Virtues related to responsible behavior and awareness of consequences (12/10.6%)	1.2.1. Responsibility
2. Virtues related to the application of GM crops (22/19.5%)	2.1. Virtues related to temperance in application of GM crops (16/6.4%)	2.1.1. Humility (11/9.7%)
		2.1.2. Wisdom (6/5.3%)
	2.2. Virtues related to integration into nature (8/3.2%)	2.2.1. Care (5/4.4%)
		2.2.2. Justice (4/3.5%)
	2.3. Virtues related to respect for non-human life (7/2.8%)	2.3.1. Appreciation

Multiple assignments of articles were possible. In brackets: number and proportion of articles

Most articles did not discuss virtues as such (n = 34), but dealt indirectly with concerns about the actor by speaking of trust, precaution, or responsibility in handling with risks (e.g., Altmann and Ammann 1992; Segal 2001). Nevertheless, in 14 articles concerns about the actor were addressed in detail: five articles discussed different types of virtue concerns (Bruce 2002b; Deane-Drummond 2002; Pascalev 2003; Sandler 2004; Kirkham 2006) and nine articles dealt with certain virtues such as trustworthiness, precaution, respect, or humility (Scott 2000; Mayer and Stirling 2002; Myhr and Traavik 2002; Bruce 2002a; Bruce 2003; Vogel 2003; Scott 2003; Munnichs 2004; Paula and Birrer 2006).

Virtues Related to the Handling of Risks

Virtues related to the handling of risks are trustworthiness and responsibility (see Table 6). The virtue of *trustworthiness* referred to trust (or distrust) of the public towards scientific researchers, regulatory procedures, as well as political and economic institutions (e.g., Scott 2003; Munnichs 2004). The virtue of *responsibility* referred to a general awareness of humans of the outcomes of their work and research (Altmann and Ammann 1992), care for the environment (Myhr and Traavik 2002), and care for the future (Deblonde and du Jardin 2005). Virtues related to the handling of risks are only indirectly dealing with environmental concerns as they focus on how scientists should behave and what the public (as consumers) can expects from sciences, politics, and the market. Thus, they are linked to socio-economic questions.

Virtues Related to the Application of GM Crops

Virtues referring to the application of GM crops were humility, wisdom, care, justice, and appreciation (see Table 6). The virtues *humility* and *wisdom* call for *temperance in the application of GM crops*. Humility acknowledges that humans can never entirely know the outcomes of their actions (Vogel 2003). This virtue is morally required for a proper understanding of human's relationship with the natural environment (Sandler 2004) and implies a certain handling of scientific procedures and knowledge (Mayer and Stirling 2002). Seen this way, the precautionary principle embodies humility regarding scientific procedures and knowledge (Mayer and Stirling 2002). The virtue of wisdom acknowledges that humans have to interact cautiously with their environment to avoid a domination of nature. Wisdom is closely related to the virtues of prudence, temperance, precaution, and practical wisdom (Deane-Drummond 2002).[12]

The virtues of *care* and *justice* apply to motivations and attitudes concerning humans' *integration into nature*. Care is related, for instance, to questions regarding the technological development (Atkinson 2002) or the sustainable approach in agriculture (Osborn 2002; Verhoog et al. 2003). The virtue of justice is understood

[12] We agree with Celia Deane-Drummond (2002) who states that the virtue of wisdom includes the virtues of prudence, temperance, precaution, and practical wisdom. Therefore, as long as these virtues were mentioned, they were considered as the virtue of wisdom.

as a disposition that takes into account the importance of non-human species as part of the overall ecological community (e.g., Deane-Drummond 2002). Justice is said to embody questions dealing with the precautionary principle (Deane-Drummond 2002; Osborn 2002).

The virtue of *appreciation* is ***related to the respect for non-human life***, e.g., the respect for the abilities and vulnerabilities of non-human life (Wenz 1999), the respect for the existence of individual life-projects and goals (Westra 1998), or the reverence for the autonomy of nature as a whole (Katz 1993; Dobson 1995). As appreciation is dealing with the relationship of humans with nature, it is linked to deontological questions concerning the value of nature and its biotic entities (cf. Westra 1998).

Discussion

Overview of the Academic Debate on GM Crops

We have identified three types of moral concerns in the academic debate on GM crops: (1) *moral concerns about the consequences* of the modification or of the outcomes of GM crops in the environment (associated with *consequentialist ethics*), (2) *moral concerns addressing the act* of modifying the genome of plants per se (associated with *deontological ethics*), and (3) *moral concerns addressing the actor's character traits and attitudes* affected by applying gene technology (associated with *virtue ethics*).

The ethical literature on gene technology often conceives the discussion as a disagreement between two moral concerns: consequentialist and deontological concerns (e.g., Runtenberg 1997; Reiss and Straughan 2002). However, our study shows that virtue concerns were also present in the debate, especially since 2001. This might reflect the growing interest in virtue concerns in environmental ethics in general (cf. Deane-Drummond 2004; Sandler and Cafaro 2004; Sandler 2007). Nevertheless, our results have to be taken with care: they might not be representative for the entire academic debate on moral concerns about the release of GM crops in agriculture as we deliberately selected certain types of journals.

Moral Concerns About the Use of GM Crops in the Academic Debate

Moral concerns addressing consequences invoked rarely the impact on individual plants (but see Balzer et al. 2000). Holtug (2001) stated that in context of the "harm principle," which in his opinion has to be the moral basis for the regulation of GM food, holistic entities such as biotic communities and plants as non-sentient entities are often excluded as they cannot suffer. However, in recent years it is discussed how to ascribe a morally relevant value to certain characteristics of plants in a consequentialist sense. One example is the "value of flourishing"[13] by Kallhoff (2002). This concept implies that it is in the "interest" of a plant to develop and

[13] In German: "Wert des pflanzlichen Gedeihens."

grow according to its species-specific characteristics, complete its life cycle and flourish in a stress-free environment. In a similar way, Attfield (2003) ascribed an intrinsic value to individual plants, including GM crops, as they can grow, photosynthesize and respire, reproduce and self-repair.

The lack of articles dealing with the intrinsic value of individual organisms in a consequentialist way might be due to our focus on plants. Plants have no interests as they lack the ability to feel and express pain, which is crucial for sentientist consequentialism to assign the intrinsic value to a biotic entity. Reiss and Straughan (2002) pointed out that questions about the moral status of organisms are more important in the debate on transgenic animals. Regarding transgenic plants, socio-economic questions are said to be more prominent (cf. Reiss and Straughan 2002; Gonzalez 2007). This was also reflected by our finding that articles referring to general environmental consequences of GM crops often dealt with questions concerning socio-economic aspects (e.g., Goga and Clementi 2002; Bruce 2002a; Bruce 2003). Even articles in natural sciences journals ("Science" and "Nature") dealt with socio-economic concerns such as concerns about food security and living conditions of farmers in developing countries (e.g., Serageldin 1999; Wambugu 1999).

General ecological concerns were often directed to risk assessment and risk management. This can be explained by the controversial debate on the underlying principles of risk assessment, following the adoption of the Cartagena Protocol in 2000 (cf. Nisbet and Huge 2007). Since then, the ethical implications of the precautionary principle and of the concept of substantial equivalence[14] were broadly discussed (e.g., Pouteau 2000). This is also reflected in the increasing number of articles addressing risk assessment (especially the precautionary principle) after the turn of the century in our literature review (e.g., Mayer and Stirling 2002; Skorupinski 2002; Myhr and Traavik 2003a; Myhr and Traavik 2003b). One element of this discourse are concerns about (scientific) uncertainty that are frequently addressed in the literature (e.g., Kasanmoentalib 1996; Carr and Levidow 2000; Myhr and Traavik 2002; Böschen et al. 2006). Uncertainty is closely related to questions about the acceptability of certain risks, the trade off between benefits and harms, and scientific research or risk assessment as such. In this context, questions arise with which scientists are unfamiliar, for example how to define acceptable ecological risks, how to address different risk perceptions in a liberal society (e.g., Jensen 2006), or how to deal with different approaches in risk assessment in Europe and in the United States (e.g., Ramjoué 2007).

General ecological concern not only addressed risk assessment, but also the future of agriculture and the possible contribution of gene technology to a sustainable development. In articles discussing sustainable agriculture most often the safety of GM crops, the value of naturalness (used especially in context of organic farming), or socio-economic questions like the market concentration in global seed industry are addressed. However, the contribution of gene technology to a sustainable agriculture is a controversially discussed concern in the literature, i.e.,

[14] Sustainable equivalence is a concept that states that GM food should be considered the same as conventional food if it shows the same characteristics and composition as the conventional food.

whether gene technology is a sustainable approach or not. This controversy might be based on different understandings and definitions of sustainable agriculture. This is especially true if only organic farming is considered as a sustainable form of agriculture (cf. Verhoog 1997).

Moral concerns addressing the act, in particular those about naturalness, were common in the reviewed literature. Using naturalness in a normative sense either for or against gene technology is seen as a "naturalistic fallacy" (for instance, criticized by Comstock 1989 and Myskja 2006). A naturalistic fallacy is committed whenever a statement or argument attempts to prove that something *is* in a certain way natural and therefore *ought to be* that way. It has also been criticized that concerns about naturalness are quite meaningless, as there are many different meanings and types of naturalness (Cooley and Goreham 2004; Siipi 2008).

Concerns about the value of biotic entities were less prominent in the reviewed literature than concerns about the value of naturalness. Most often, an intrinsic value was assigned to holistic biotic entities such as species, ecosystems or the biotic community, whereas only few articles assigned an intrinsic value to individual plants. Even among environmental ethicists no consensus exists whether an intrinsic value can be assigned to individual plants (e.g., Melin 2004).

Moral concerns addressing the actor were linked in several articles to moral concerns addressing the act (pointing to deontological ethics) (e.g., Katz 1993; Westra 1998; Kirkham 2006). For instance, notions such as "vexing nature" or "playing God," which are used in context of act-orientated concerns, also have virtue-based implications invoking questions about the purpose of technology and the place of humanity within the natural environment (Kirkham 2006). Among actor-based concerns, *virtues that are related to the handling of risks* were important. Most often, the virtues of trustworthiness (of science as well as of politics and the market) and responsibility were mentioned. These virtues imply that actors are concerned about their actions and act in ways that promote or maintain environmental goods or values. When focusing on risks and benefits, i.e., on the outcome of gene technology, virtues like responsibility can be linked to concerns about consequences.

In the last decade, virtues such as humility, wisdom, care, justice, and appreciation have received increasing attention in environmental ethics. These virtues, which we grouped under the header of "*virtues related to the application of GM crops*," are justified by the worth of living organisms and humans' relationship with nature (cf. Sandler 2007). Because living organisms are valuable, humans have to behave prudently and respectfully towards them. Seen in this way, virtues related to the application of GM crops deal with the respect for living organisms and can overlap with act-orientated concerns. For example, the virtue of humility and the closely related virtue of caution can be linked to the concept of ecological integrity (Westra 1998). Moreover, virtues related to the application of GM crops can be linked to concerns addressing consequences. For instance, the precautionary principle with its aim to minimize ecological risks is based on consequentialist concerns. However, precaution is also related to attitudes of an actor, especially to the virtues of wisdom and care (cf. Deane-Drummond 2002; Mayer and Stirling

2002). To have such a virtue-based interpretation of the precautionary principle in mind is helpful to avoid misunderstandings in the public debate.

Virtue concerns can be linked to other type of moral concerns, i.e., concerns addressing the act and concerns addressing consequences. Moral concerns addressing the actor can thus help to overcome the often presupposed dichotomy of consequentialist and deontological concerns in the debate on the use GM crops. Pluralistic forms of virtue ethics theories exist that integrate non-virtue-based reasons that play a role in deontology or consequentialism (Crisp 2003). For instance, it was stated by Hursthouse (2003) that virtue ethics appears to stand "shoulder to shoulder" with deontology. With the focus on the individual person's character traits, virtue ethics add a new viewpoint to the overall ethical debate, as the actor is not the prime focus in consequentialism or deontology.

In the reviewed literature, environmental concerns were closely linked to socio-economic concerns in several articles, for example, to questions about ecological and social justice or to the trustworthiness of science, politics, and the market (e.g., Wambugu 1999; Scott 2000; Scott 2003; Goga and Clementi 2002; Bruce 2002a; Bruce 2003). This shows that the debate about the ecological and environmental ethical aspects of GM crops is also a debate about the role of science, the role of politics and the market, and the role of laypersons in public as consumers. It is therefore doubtful whether the environmental debate on GM crops can be held separately from the debate on socio-economic aspects or whether they are mutually dependent.

Comparison of the Academic and Laypersons' Debate on the Use of GM Crops

Moral concerns of laypersons play an important role in the public debate on GM crops. Although moral concerns and arguments similar to those expressed by academics are put forward by laypersons in the public debate, laypersons' concerns do not only reflect scientific arguments associated with gene technology (cf. Harlander 1991), but also more fundamental personal beliefs (Hoban et al. 1992). Moreover, the risk perception between laypersons and scientific experts (in the field of biological sciences) differs in certain points: experts significantly and systematically perceive biotechnology as less risky than laypersons do (Savadori et al. 2004; Sjöberg 2008) and consider its applications in food production as more useful (Savadori et al. 2004). However, despite these dissimilarities *moral concerns addressing consequences* are prominent in the public debate on GM crops or GM food, too (e.g., Frewer et al. 1997a; Saba et al. 1998; Gaskell 2000; Gaskell et al. 2000; Magnusson and Koivisto Hursti 2002; Amin et al. 2007; Chen and Li 2007; Henson et al. 2008).

Moral concerns addressing the act are often invoked in the moral reasoning of laypersons (Hansen et al. 2003; Frewer et al. 2004; Siegrist 2008; Tanner et al. 2008). This is especially true for concerns about naturalness: about 65% of the participants in the 2002 Eurobarometer survey agreed that GM food threatens the natural order of things (Peters and Sawicka 2007). Concerns about the loss of naturalness have been recognized as important constituents of unease among the public (e.g., Reif and Melich 1996; Frewer et al. 1997b; Melich 2000). Naturalness

concerns are often addressed by the public to express a desire for a world untouched by humans (Dürnberger 2008). However, laypersons are less concerned about the infringement of the intrinsic value in modifying plants than in the modification of animals (cf. Frewer et al. 1997a; Kinsey and Senauer 1997; Ganiere et al. 2006). In the academic debate, the moral status of plants appears to be less important.

In contrast to concerns addressing consequences or the act itself, ***moral concerns addressing the actor*** were rarely found in recent studies on the laypersons' perception of gene technology. However, several surveys have shown that trustworthiness is crucial for laypersons (Brown and Ping 2003; Frewer 2003; Gaskell et al. 2003; Hansen et al. 2003; Frewer et al. 2004; Savadori et al. 2004; Chen and Li 2007; Siegrist 2008). Therefore, virtues essential for handling risks are important for initiating and establishing a dialogue between academic experts and laypersons.

Similar to academic experts, laypersons base their moral reasoning about GM crops on concerns about perceived risks, unnaturalness, and personal ethical beliefs. However, conflicts within the public about GM crops are not likely to be solved by more knowledge about potential ecological risks. These conflicts are deeply rooted in personal ideas about life and nature, i.e., deontological and virtue concerns, which are important for the moral reasoning of laypersons, as recent psychological research showed (Tanner et al. 2008). Social and psychological scientists could help to identify factors that motivate and lead people to certain attitudes towards gene technology. Knowing the motivations of others makes it easier to take their position seriously, accepting that they do not act in bad faith but simply against a different normative backdrop. In this regard, ethicists are important for the dialogue between academic experts and laypersons in the public: they can discuss how moral concerns are used by laypersons and how a sound and well-grounded moral reasoning has to be established. Moreover, natural scientists can contribute to the debate with their expertise on ecological concerns. Knowledge of risks and benefits is fundamental for moral reasoning, especially for consequentialist ethics.

Conclusions

The literature review showed that there is no single dichotomy between moral concerns addressing consequences and the act, i.e., consequentialist and deontological concerns. Moral concerns addressing the actor, i.e., virtue concerns, were also present and linked with the other two concerns (cf. Crisp 2003; Hursthouse 2003). Environmental virtue ethics with its focus on the individual actor could help to bridge the split between deontological and consequentialist concerns. Psychological research on act choices (Tanner et al. 2008) indicates that deontological and consequentialist concerns are not mutually exclusive in the reasoning of laypersons: different types of moral concerns are often intertwined in laypersons' decision-making on act choices.

The perception of gene technology by academic experts, especially by natural scientists, differs from that of laypersons. The moral reasoning of academic experts is well-founded on ecological concerns; their arguments are carefully considered

and critically discussed. However, among laypersons, ecological concerns are more often associated with personal lifestyles and individual preferences (Korthals 2001; Meijboom et al. 2003). Ethics as the discipline that analyzes and justifies moral reasoning could help to take into account moral concerns of the general public in the debate on the use of GM crops by establishing an "empirically informed ethics" (cf. Musschenga 2005). Empirically informed ethics combines doing empirical research with philosophical analysis and reflection (Musschenga 2005). It could improve the context sensitivity in the debate on GM crops, for example, by addressing the personal lifestyles of laypersons. As consumers, laypersons are not only concerned with risk and safety of GM crops, but also follow personal preferences in their decisions (Korthals 2001). Ethicists could bridge the gap between the moral perception of (natural) scientists and laypersons with the help of an empirically informed ethics.

In moral philosophy, models are used that help to structure and analyze a moral debate. Moreover, practical tools for decision-making processes that integrate different moral concerns are provided. Such models and tools were developed, for instance, by Fraser (2001), Busch et al. (2002), Forsberg (2007) and Mepham (2008). The aim of such tools is to support a systematic public deliberation about the ethical aspects of agricultural biotechnologies (Beekman and Brom 2007). However, they rarely include virtue concerns and, if so, only address the virtue of justice. The present results exemplify the relevance of different virtues in the ecological discourse on the release of GM crops that should be integrated in the respective models and tools. They can help to overcome the focus in the debate on deontology and consequentialism. An example of how to integrate virtue concerns is the tool for ethical decision-making by Bleisch and Huppenbauer (2011).

Our study is the first to provide a comprehensive overview of the moral reasoning expressed in academic publications on the use of GM crops. It shows which types of moral concerns are expressed in the debate, how they are mutually linked, and could thus contribute to a better understanding of the academic debate on the release of GM crops. It would be helpful to investigate the public debate in the same way. To know the various types of moral concerns and their different usage in the academic as well as in the public debate would be a crucial starting point to develop a fruitful dialogue between sciences and the general public.

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References

Altmann, M., & Ammann, K. (1992). Gentechnologie im gesellschaftlichen Spannungsfeld: Züchtung transgener Kulturpflanzen. *GAIA, 1*(4), 204–213.

Amin, L., Jahi, J., Nor, A. R., Osman, M., & Mahadi, N. M. (2007). Public acceptance of modern biotechnology. *Asia Pacific Journal of Molecular Biology and Biotechnology, 15*(2), 39–51.

Ammann, K., Jacot, Y., & Braun, R. (Eds.). (2003). *Methods for risk assessment of transgenic plants, IV. Biodiversity and biotechnology*. Basel: Birkhäuser Verlag.

Annas, J. (2006). Virtue ethics. In D. Copp (Ed.), *The Oxford handbook of ethical theory* (pp. 515–536). New York: Oxford University Press.

Atkinson, D. (2002). Agriculture–reconciling ancient tensions. *Ethics in Science and Environmental Politics, 2*(2002), 52–58.

Attfield, R. (2003). *Environmental ethics*. Cambridge: Polity Press.

Balzer, P., Rippe, K. P., & Schaber, P. (1998). *Menschenwürde vs. Würde der Kreatur*. München: Alber.

Balzer, P., Rippe, K. P., & Schaber, P. (2000). Two concepts of dignity for humans and non-human organisms in the context of genetic engineering. *Journal of Agricultural and Environmental Ethics, 13*(1), 7–27.

Beekman, V., & Brom, F. W. A. (2007). Ethical tools to support systematic public deliberations about the ethical aspects of agricultural biotechnologies. *Journal of Agricultural and Environmental Ethics, 20*(1), 3–12.

Birnbacher, D. (2007). *Analytische Einführung in die Ethik*. Berlin and New York: Walter de Gruyter.

Bleisch, B., & Huppenbauer, M. (2011). *Ethische Entscheidungsfindung. Ein Handbuch für die Praxis*. Zürich: Versus Verlag.

Böschen, S., Kastenhofer, K., Marschall, L., Rust, I., Soentgen, J., & Wehling, P. (2006). Scientific cultures of non-knowledge in the controversy over genetically modified organisms (GMO). *GAIA, 15*(4), 294–301.

Brennan, A., & Y.-S. Lo. (2008). Environmental ethics. In Stanford Encyclopedia of Philosophy, first published Mon Jun 3, 2002; substantive revision Thu Jan 3, 2008, plato.stanford.edu/entries/ethics-environmental/.

Brink, D. O. (2006). Some forms and limits of consequentialism. In D. Copp (Ed.), *The Oxford handbook of ethical theory* (pp. 380–423). New York: Oxford University Press.

Brookes, G., & Barfoot, P. (2005). GM crops: the global economic and environmental impact—the first nine years 1996–2004. *AgBioForum, 8*(2&3), 187–196.

Brown, J. L., & Ping, Y. (2003). Consumer perception of risk associated with eating genetically engineered soybeans is less in the presence of a perceived consumer benefit. *Journal of the American Dietetic Association, 103*(2), 208–214.

Bruce, D. (2002a). A social contract for biotechnology: Shared visions for risky technologies? *Journal of Agricultural and Environmental Ethics, 15*(3), 279–289.

Bruce, D. (2002b). GM ethical decision making in practice. *Ethics in Science and Environmental Politics, 2*(2002), 75–78.

Bruce, D. (2003). Contamination, crop trials, and compatibility. *Journal of Agricultural and Environmental Ethics, 16*(6), 595–604.

Burkhardt, J. (2001). Agricultural biotechnology and the future benefits argument. *Journal of Agricultural and Environmental Ethics, 14*(2), 135–145.

Busch, R. J., Knoepffler, N., Haniel, A., & Wenzel, G. (2002). *Grüne Gentechnik. Ein Bewertungsmodell*. München: Utz Verlag.

Carr, S. (2002). Ethical and value-based aspects of the European commission's precautionary principle. *Journal of Agricultural and Environmental Ethics, 15*(1), 31–38.

Carr, S., & Levidow, L. (2000). Exploring the links between science, risk, uncertainty, and ethics in regulatory controversies about genetically modified crops. *Journal of Agricultural and Environmental Ethics, 12*(1), 29–39.

Chen, M.-F., & Li, H.-L. (2007). The consumer's attitude toward genetically modified foods in Taiwan. *Food Quality and Preference, 18*(4), 662–674.

Clark, E. A., & Lehmann, H. (2001). Assessment of GM crops in commercial agriculture. *Journal of Agricultural and Environmental Ethics, 14*(1), 3–28.

Cohen, S. N. (1977). Recombinant DNA: Fact and fiction. *Science, 195*(4279), 654–657.

Comstock, G. (1989). Genetically engineered herbicide resistance, Part One. *Journal of Agricultural and Environmental Ethics, 2*(4), 263–306.

Comstock, G. (1990). Genetically engineered herbicide resistance, Part Two. *Journal of Agricultural and Environmental Ethics, 3*(2), 114–146.

Cooley, D. R., & Goreham, G. A. (2004). Are transgenic organisms unnatural? *Ethics and The Environment, 9*(1), 46–55.

Cowgill, S. E., Danks, C., & Atkinson, H. J. (2004). Multitrophic interactions involving genetically modified potatoes, nontarget aphids, natural enemies and hyperparasitoids. *Molecular Ecology, 13*(3), 639–647.

Crisp, R. (2003). Modern moral philosophy and the virtues. In R. Crisp (Ed.), *How should one live? Essays on the Virtues* (pp. 1–18). Oxford: Oxford University Press.

Deane-Drummond, C. E. (2002). Wisdom with justice. *Ethics in Science and Environmental Politics, 2*(2002), 65–74.

Deane-Drummond, C. E. (2004). *The ethics of nature*. Malden: Blackwell Publication.

Deblonde, M., & du Jardin, P. (2005). Deepening a precautionary European policy. *Journal of Agricultural and Environmental Ethics, 18*(4), 319–343.

Deckers, J. (2005). Are scientists right and non-scientists wrong? Reflections on discussions of GM. *Journal of Agricultural and Environmental Ethics, 18*(5), 451–478.

Devos, Y., Maeseele, P., Reheul, D., van Speybroeck, L., & de Waele, D. (2008). Ethics in the societal debate on genetically modified organisms: A (re)quest for sense and sensibility. *Journal of Agricultural and Environmental Ethics, 21*(1), 29–61.

Dickson, D. (1980). Patenting living organisms—how to beat the bug-rustlers. *Nature, 283*(5743), 128–129.

Dobson, A. (1995). Biocentrism and genetic engineering. *Environmental Values, 3*(4), 227–239.

Dürnberger, C. (2008). Der Mythos der Ursprünglichkeit–Landwirtschaftliche Idylle und ihre Rolle in der öffentlichen Wahrnehmung. *Forum TTN, 2008*(19), 45–52.

Duvick, D. N. (1995). Biotechnology is compatible with sustainable agriculture. *Journal of Agricultural and Environmental Ethics, 8*(2), 112–125.

Elliott, E. T., & Cole, C. V. (1989). A perspective on agroecosystem science. *Ecology, 6*(70), 1597–1602.

Firbank, L. G., & Forcella, F. (2000). Genetically modified crops and farmland biodiversity. *Science, 289*(5484), 1481–1482.

Forsberg, E.-M. (2007). Value pluralism and coherentist justification of ethical advice. *Journal of Agricultural and Environmental Ethics, 20*(1), 81–97.

Fraser, V. (2001). What's the moral of the GM food story? *Journal of Agricultural and Environmental Ethics, 14*(2), 147–159.

Frewer, L. J. (2003). Societal issues and public attitudes towards genetically modified foods. *Trends in Food Science and Technology, 14*(5–8), 319–332.

Frewer, L. J., Hedderley, D., Howard, C., & Shepherd, R. (1997a). 'Objection' mapping in determining group and individual concerns regarding genetic engineering. *Agriculture and Human Values, 14*(1), 67–79.

Frewer, L. J., Howard, C., & Shepherd, R. (1997b). Public concerns in the United Kingdom about general and specific applications of genetic engineering: Risk, benefit, and ethics. *Science, Technology and Human Values, 22*(1), 98–124.

Frewer, L. J., Lassen, J., Kettlitz, B., Scholderer, J., Beekman, V., & Berdal, K. G. (2004). Societal aspects of genetically modified foods. *Food and Chemical Toxicology, 42*(7), 1181–1193.

Ganiere, P., Chern, W., & Hahn, D. (2006). A continuum of consumer attitudes toward genetically modified foods in the United States. *Journal of Agricultural and Resource Economics, 31*(1), 129–149.

Gaskell, G. (2000). Agricultural biotechnology and public attitudes in the European Union. *AgBioForum, 3*(2–3), 87–96.

Gaskell, G., N. Allum, & S. Stares. (2003). Europeans and biotechnology in 2002—Eurobarometer 58.0 (2nd Edn. March 21st 2003). A report to the EC Directorate General for Research from the project 'Life Sciences in European Society' QLG7-CT-1999-00286.

Gaskell, G., Allum, N., Bauer, M., Durant, J., Allansdottir, A., Bonfadelli, H., et al. (2000). Biotechnology and the European public. *Nature Biotechnology, 18*(9), 935–938.

Gaus, G. F. (2001a). What is deontology? Part one: Orthodox views. *The Journal of Value Inquiry, 35*(1), 27–42.

Gaus, G. F. (2001b). What is deontology? Part two: Reasons to act. *The Journal of Value Inquiry, 35*(2), 179–193.

Goga, B. T. C., & Clementi, F. (2002). Safety assurance of foods: Risk management depends on good science but it is not a scientific activity. *Journal of Agricultural and Environmental Ethics, 15*(3), 305–313.

Gonzalez, C. G. (2007). Genetically modified organisms and justice: The international environmental justice implications of biotechnology. *Georgetown International Environmental Law Review, 19*(4), 583–610.

Gura, T. (2001). The battlefields of Britain. *Nature, 412*(6849), 760–763.
Hails, R. S. (2000). Genetically modified plants—the debate continues. *Trends in Ecology & Evolution, 15*(1), 14–18.
Hails, R. S. (2002). Assessing the risks associated with new agricultural practices. *Nature, 418*(6898), 685–688.
Hansen, J., Holma, L., Frewer, L. J., Robinson, P., & Sandøe, P. (2003). Beyond the knowledge deficit: recent research into lay and expert attitudes to food risks. *Appetite, 41*(2), 111–121.
Harlander, S. K. (1991). Social, moral, and ethical issues in food biotechnology. *Food Technology, 45*(5), 152–159.
Harwood, J. D., Wallin, W. G., & Obrycki, J. J. (2005). Uptake of Bt endotoxins by nontarget herbivores and higher order arthropod predators: Molecular evidence from a transgenic corn agroecosystem. *Molecular Ecology, 14*, 2815–2823.
Heaf, D., & J. Wirz. (Eds.) (2002). Genetic engineering and the intrinsic value and integrity of animals and plants. Proceedings of a Workshop at the Royal Botanic Garden, Edinburgh. Hafan: Ifgene.
Heeger, R. (2000). Genetic engineering and the dignity of creatures. *Journal of Agricultural and Environmental Ethics, 13*(1), 43–51.
Henson, S., Annou, M., Cranfield, J., & Ryks, J. (2008). Understanding consumer attitudes toward food technologies in Canada. *Risk Analysis, 28*(6), 1601–1617.
Herold, N. (2008). Pflicht ist Pflicht! Oder nicht? Eine Einführung in die Deontologische Ethik. In J. S. Ach, K. Bayertz, & L. Siep (Eds.), *Grundkurs Ethik. Band 1: Grundlagen* (pp. 71–90). Paderborn: Mentis Verlag.
Ho, M.-W., Ryan, A., & Cummins, J. (1999). Cauliflower mosaic viral promoter—a recipe for disaster? *Microbial Ecology in Health and Disease, 11*(4), 194–197.
Hoban, T. J., Woodrum, E., & Czaja, R. (1992). Public opposition to genetic engineering. *Rural Sociology, 57*(4), 476–493.
Hoffman, C. A., & Carroll, C. R. (1995). Can we sustain the biological basis of agriculture? *Annual Review of Ecology, Evolutionand Systematics, 26*(1995), 69–92.
Holtug, N. (2001). The harm principle and genetically modified food. *Journal of Agricultural and Environmental Ethics, 14*(2), 169–178.
Howard, J. A., & Donnelly, K. C. (2004). A quantitative safety assessment model for transgenic protein products produced in agricultural crops. *Journal of Agricultural and Environmental Ethics, 17*(6), 545–558.
Hursthouse, R. (2003). Normative virtue ethics. In R. Crisp (Ed.), *How should one live? Essays on the virtues* (pp. 19–36). Oxford: Oxford University Press.
Jensen, K. K. (2006). Conflict over risks in food production: A challenge for democracy. *Journal of Agricultural and Environmental Ethics, 19*(3), 269–283.
Kallhoff, A. (2002). *Prinzipien der Pflanzenethik. Die Bewertung pflanzlichen Lebens in Biologie und Philosophie*. New York: Frankfurt, Campus Verlag.
Karafyllis, N. C. (2003). Renewable resources and the idea of nature—what has biotechnology got to do with it? *Journal of Agricultural and Environmental Ethics, 16*(1), 3–28.
Kasanmoentalib, S. (1996). Science and values in risk assessment: The case of deliberate release of genetically engineered organisms. *Journal of Agricultural and Environmental Ethics, 9*(1), 42–60.
Katz, E. (1993). Artefacts and functions: A note on the value of nature. *Environmental Value, 2*(3), 223–232.
Kinsey, J., & Senauer, B. (1997). Food marketing in an electronic age: Implications for agriculture. *Choices, 12*(2nd Quarter), 32–35.
Kirkham, G. (2006). 'Playing god' and 'vexing nature': A cultural perspective. *Environmental Values, 15*(2), 173–195.
Korthals, M. (2001). Taking consumers seriously: Two concepts of consumer sovereignty. *Journal of Agricultural and Environmental Ethics, 14*(2), 201–215.
Kotschi, J. (2008). Transgenic crops and their impact on biodiversity. *GAIA., 17*(1), 36–41.
Krebs, J. R., Bradbury, R. B., Wilson, J. D., & Siriwardena, G. M. (1999). The second silent spring? *Nature, 400*(6753), 611–612.
Lammerts van Bueren, E., & Struik, P. (2005). Integrity and rights of plants: ethical notions in organic plant breeding and propagation. *Journal of Agricultural and Environmental Ethics, 18*(5), 479–493.
Madsen, K. H., & Sandøe, P. (2001). Herbicide resistant sugar beet—What is the problem? *Journal of Agricultural and Environmental Ethics, 14*(2), 161–168.

Madsen, K. H., Holm, P. B., Lassen, J., & Sandøe, P. (2002). Ranking genetically modified plants according to familiarity. *Journal of Agricultural and Environmental Ethics, 15*(3), 267–278.

Magnusson, M. K., & Koivisto Hursti, U.-K. (2002). Consumer attitudes towards genetically modified foods. *Appetite, 39*(1), 9–24.

Marvier, M. (2002). Improving risk assessment for nontarget safety of transgenic crops. *Ecological Applications, 12*(4), 1119–1124.

Marvier, M., & Van Acker, R. C. (2005). Can crop transgenes be kept on a leash? *Frontiers in Ecology and Environment, 3*(2), 99–106.

Mayer, S., & Stirling, A. (2002). Finding a precautionary approach to technological developments—lessons for the evaluation of GM crops. *Journal of Agricultural and Environmental Ethics, 15*(1), 57–71.

McNaughton, D., & Rawling, P. (2006). Chapter 15. Deontology. In D. Copp (Ed.), *The Oxford handbook of ethical theory* (pp. 425–458). New York: Oxford University Press.

Meijboom, F. L. B., Verweij, M. F., & Brom, F. W. A. (2003). You eat what you are: moral dimensions of diets tailored to one's genes. *Journal of Agricultural and Environmental Ethics, 16*(6), 557–568.

Melich, A. (2000). Modern biotechnology, quality of life, and consumers' access to justice—eurobarometer 52.1 (Nov–Dec 1999). Conducted by INRA (Europe), Brussels. ICPSR02893-v4. Cologne, Germany: GESIS/Ann Arbor, MI. Inter-University Consortium for Political and Social Research [distributors].

Melin, A. (2004). Genetic engineering and the moral status of non-human species. *Journal of Agricultural and Environmental Ethics, 17*(6), 479–495.

Mepham, B. (2008). *Bioethics. An introduction for the biosciences* (Second edition ed.). Oxford, New York: Oxford University Press.

Munnichs, G. (2004). Whom to trust? Public concerns, late modern risks, and expert trustworthiness. *Journal of Agricultural and Environmental Ethics, 17*(2), 113–130.

Musschenga, A. (2005). Empirical ethics, context-sensitivity, and contextutalism. *Journal of Medicine and Philosophy, 30*(5), 467–490.

Myhr, A. I., & Traavik, T. (2002). The precautionary principle: scientific uncertainty and omitted research in the context of GMO use and release. *Journal of Agricultural and Environmental Ethics, 15*(1), 73–86.

Myhr, A. I., & Traavik, T. (2003a). Genetically modified (GM) crops: Precautionary science and conflicts of interests. *Journal of Agricultural and Environmental Ethics, 16*(3), 227–247.

Myhr, A. I., & Traavik, T. (2003b). Sustainable development and Norwegian genetic engineering regulations: Applications, impacts, and challenges. *Journal of Agricultural and Environmental Ethics, 16*(4), 317–335.

Myskja, B. K. (2006). The moral difference between intragenic and transgenic modification of plants. *Journal of Agricultural and Environmental Ethics, 19*(3), 225–238.

Nisbet, M. C., & Huge, M. (2007). Where do science debates come from? Understanding attention cycles and framing. In D. Brossard, J. Shanahan, & T. C. Nesbitt (Eds.), *The media, the public and agricultural biotechnology* (pp. 193–230). London: CABI Publishing.

O'Neill, J., Holland, A., & Light, A. (2006). *Environmental values (Routledge Introductions to Environment)*. New York: Routledge Group.

Osborn, D. (2002). Stretching the frontiers of precaution. *Ethics in Science and Environmental Politics, 2*(2002), 37–41.

Pascalev, A. (2003). You are what you eat: genetically modified foods, integrity, and society. *Journal of Agricultural and Environmental Ethics, 16*(6), 583–594.

Paula, L., & Birrer, F. (2006). Including public perspectives in industrial biotechnology and the biobased economy. *Journal of Agricultural and Environmental Ethics, 19*(3), 253–267.

Peters, H. P., & Sawicka, M. (2007). German reactions to genetic engineering in food production. In D. Brossard, J. Shanahan, & T. C. Nesbitt (Eds.), *The public, the media and agricultural biotechnology (pp.57–96)*. Wallingford (UK): CABI Publishing.

Pilson, D., & Prendeville, H. R. (2004). Ecological effects of transgenic crops and the escape of transgenes into wild populations. *Annual Review of Ecology, Evolution, and Systematics, 35*(1), 149–174.

Pouteau, S. (2000). Beyond substantial equivalence: Ethical equivalence. *Journal of Agricultural and Environmental Ethics, 13*(3–4), 271–291.

Ramjoué, C. (2007). The transatlantic rift in genetically modified food policy. *Journal of Agricultural and Environmental Ethics, 20*(5), 419–436.

Regal, P. J. (1994). Scientific principles for ecologically based risk assessment of transgenic organisms. *Molecular Ecology, 3*(1), 5–13.

Reif, K., & A. Melich. (1996). Biotechnology and genetic engineering: What Europeans think about biotechnology—Eurobarometer 39.1 (First ICPSR Edition, April 1996). Conducted by INRA (Europe), Brussels. ICPSR ed. Ann Arbor, MI. Interuniversity Consortium for Political and Social Research [producer], Köln. Zentralarchiv für Empirische Sozialforschung/Ann Arbor, MI. Inter-University Consortium for Political and Social Research [distributors].

Reiss, M. J., & Straughan, R. (2002). *Improving nature*. Cambridge: Cambridge University Press.

Rippe, K. P., & Schaber, P. (1998). Einleitung. In K. P. Rippe & P. Schaber (Eds.), *Tugendethik* (pp. 7–18). Stuttgart: Philipp Reclam jun.

Robinson, J. (1999). Ethics and transgenic crops: A review. *Electronic Journal of Biotechnology, 2*(2), 71–81.

Rolston, H., I. I. I. (1999). *Genes, genesis and god. Values and their origins in natural and human history*. Cambridge: Cambridge University Press.

Runtenberg, C. (1997). Argumentationen im Kontext angewandter Ethik: das Beispiel Gentechnologie. In N. Herold & S. Mischer (Eds.), *Philosophie: Studium, Text und Argument* (pp. 179–193). Münster: LIT-Verlag.

Saba, A., Moles, A., & Frewer, L. J. (1998). Public concerns about general and specific applications of genetic engineering: a comparative study between the UK and Italy. *Nutrition and Food Science, 98*(1), 19–29.

Sandler, R. (2004). An aretaic objection to agricultural biotechnology. *Journal of Agricultural and Environmental Ethics, 17*(3), 301–317.

Sandler, R. (2007). *Character and environment. A virtue-oriented approach to environmental ethics*. New York: Columbia University Press.

Sandler, R., & Cafaro, P. (2004). *Environmental virtue ethics*. Lanham: Rowman and Littlefield.

Saner, M. A. (2000). Biotechnology, the limits of Norton's convergence hypothesis, and implications for an inclusive concept of health. *Ethics and the Environment, 5*(2), 229–241.

Savadori, L., Savio, S., Nicotra, E., Rumiati, R., Finucane, M., & Slovic, P. (2004). Expert and public perception of risk from biotechnology. *Risk Analysis, 24*(5), 1289–1299.

Scott, I. M. (2000). Green symbolism in the genetic modification debate. *Journal of Agricultural and Environmental Ethics, 13*(3–4), 293–311.

Scott, D. (2003). Science and the consequences of mistrust: Lessons from recent GM controversies. *Journal of Agricultural and Environmental Ethics, 16*(6), 569–582.

Scott, D. (2005). The magic bullet criticism of agricultural biotechnology. *Journal of Agricultural and Environmental Ethics, 18*(3), 259–267.

Segal, H. P. (2001). Victor and victim. *Nature, 412*(6850), 861.

Serageldin, I. (1999). Biotechnology and food security in the 21st century. *Science, 285*(5426), 387–389.

Shelton, A. M., Zhao, J.-Z., & Roush, R. T. (2002). Economic, ecological, food safety, and social consequences of the deployment of Bt transgenic plants. *Annual Review of Entomology, 47*(2002), 845–881.

Siegrist, M. (2008). Factors influencing public acceptance of innovative food technologies and products. *Trends in Food Science and Technology, 19*(11), 603–608.

Siipi, H. (2008). Dimensions of naturalness. *Ethics and the Environment, 13*(1), 71–103.

Sjöberg, L. (2008). Genetically modified food in the eyes of the public and experts. *Risk Management, 10*(3), 168–193.

Skorupinski, B. (2002). Putting precaution to debate—about the precautionary principle and participatory technology assessment. *Journal of Agricultural and Environmental Ethics, 15*(1), 87–102.

Snow, A. (2003). Genetic engineering: Unnatural selection. *Nature, 424*(6949), 619.

Stewart, C. N. (2004). *Genetically modified planet. Environmental impacts of genetically engineered plants*. New York: Oxford University Press.

Stöcklin, J. (2007). Die Pflanze. Moderne Konzepte der Biologie. Eidgenössische Ethikkommission für die Biotechnologie im Ausserhumanbereich EKAH (Eds.). Beiträge zur Ethik und Biotechnologie, Band 2.

Tanner, C., Medin, D. L., & Iliev, R. (2008). Influence of deontological versus consequentialist orientations on act choices and framing effects: When principles are more important than consequences. *European Journal of Social Psychology, 38*(5), 757–769.

Taylor, P. (1986). *Respect for nature: A theory of environmental ethics*. Princeton: Princeton University Press.

Tiedje, J. M., Colwell, R. K., Grossman, Y. L., Hodson, R. E., Lenski, R. E., Mack, R. N., et al. (1989). The planned introduction of genetically engineered organisms: Ecological considerations and recommendations. *Ecology, 70*(2), 298–315.

Verhoog, H. (1992). The concept of intrinsic value and transgenic animals. *Journal of Agricultural and Environmental Ethics, 5*(2), 147–160.

Verhoog, H. (1997). Organic agriculture versus genetic engineering. *In NJAS Wageningen Journal of Life Sciences, 54*(4), 387–400.

Verhoog, H., Matze, M., van Bueren, E. L., & Baars, T. (2003). The role of the concept of the natural (naturalness) in organic farming. *Journal of Agricultural and Environmental Ethics, 16*(1), 29–49.

Vogel, S. (2003). The nature of artifacts. *Environmental Ethics, 25*(2), 149–168.

von Kutschera, F. (1999). *Grundlagen der Ethik*. Berlin and New York: Walter de Gruyter.

Von Wartburg, W. P., & Liew, J. (1999). *Gene technology and social acceptance*. Lanham, Md: University Press of America.

Wambugu, F. (1999). Why Africa needs agricultural biotech. *Nature, 400*(6739), 15–16.

Watkinson, A. R., Freckleton, R. P., Sutherland, W. J., & Robinson, R. A. (2000). Predictions of biodiversity response to genetically modified herbicide-tolerant crops. *Science, 289*(5484), 1554–1557.

Weaver, S. A., & Morris, M. C. (2005). Risks associated with genetic modification: an annotated bibliography of peer reviewed natural science publications. *Journal of Agricultural and Environmental Ethics, 18*(2), 157–189.

Wenz, P. S. (1999). Pragmatism in practice: The efficiency of sustainable agriculture. *Environmental Ethics, 21*(4), 391–410.

Westra, L. (1998). Biotechnology and transgenics in agriculture and aquaculture: The perspective from ecosystem integrity. *Environmental Values, 7*(1), 79–96.

Woese, C. R. (2004). A New biology for a new century. *Microbiology and Molecular Biology Reviews, 68*(2), 173–186.

Wolfenbarger, L. L., & Phifer, P. R. (2000). The ecological risks and benefits of genetically engineered plants. *Science, 290*(5499), 2088–2093.